A Quality and Technology Network

European SME Implementation of Lead-Free Soldering European Overview

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2008 International Workshop on Pollution Prevention and Sustainable Development
20th November 2008
University of California - San Diego

instituto de soldadura e qualidade

Outline

- European Implementation of RoHS
- RoHS oriented SME European Research Projects
- LEADOUT Project – Overview & Final Results
- Forthcoming related projects - ELECTROVALUE

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- **European Implementation of RoHS**
- RoHS oriented SME European Research Projects
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The RoHS European Directive 2002/95/EC

Legal Scope

RoHS – Restriction of the use of certain Hazardous Substances

- **Lead (0,1%)**
- **Mercury (0,1%)**
- **Hexavalent Chromium (0,1%)**
- **PBB - polybrominated biphenyl- (0,1%)**
- **PBDE - polybrominated diphenyl ether (0,1%)**
- **Cadmium (0,01%)**

On force since 1st July 2006 requiring that new electrical equipment put on the market from this date does not contain any of the above six banned substances - Producer responsability

The RoHS Directive Implementation

In Europe

- **RoHS in force since 1st July 2006 in Europe**
- **Activities beyond RoHS implementation**

- Studies carried out on behalf of EC

- PoHS Directive - Norway

The RoHS Directive

Activities beyond RoHS implementation

Studies carried out on behalf of EC on Technical revisions of RoHS Scop DG Environment

Title: "Technical adaptation under Directive 2002/95/EC (RoHS) – Investigation of Exemptions"
Author: ERA Technology (UK)
Date: December 2004
Scope: Technical review of 3 of the applications listed in Item 10 of RoHS Annex of requests for exemptions from industry.

Title: "Adaptation to Scientific and Technical progress under Directive 2002/95/EC
Author: ÖKO –Institut and Fraunhofer IZM (DE)
Date: July 2006
Scope: Evaluation of requests for exemptions from industry accordingly with Article 5 (1)(b) of the Directive. This study looks at 88 requests.

The RoHS Directive

Activities beyond RoHS implementation

Studies carried out on behalf of EC on Technical revisions of RoHS Scope DG Environment

Title: "Adaptation to scientific and Technical Progress under Directive 2002/95/EC -Evaluation of Exemptions "
Author: ÖKO –Institut and Fraunhofer IZM (DE)
Date: 22 October 2007
Scope: Evaluation of requests for exemptions from industry accordingly with the requirements listed in Article 5 (1)(b) of the Directive.
This study looks at 34 requests.

Title: "Adaptation to scientific and Technical Progress under Directive 2002/95/EC -Review of existing exemptions and evaluation of new requests for exemptio
Author: ÖKO –Institut and Fraunhofer IZM (DE)
Date: 30 October 2007; Issue date: October 2008
Scope: Evaluation of 29 applications of lead, mercury, cadmium and hexavalent c currently in the list of exemptions in RoHS Annex. Exemptions should be every four years or 4 years after being added to the list.

Reports available at:
http://ec.europe.eu/environment/waste/studies_rohs1

The RoHS Directive

Activities beyond RoHS implementation

- **PoHS – Prohibition on certain hazardous substances in consumer products**

- The Norwegian Pollution Control Authority issued in 2007 a draft for a new chapter on Prohibition of certain hazardous Substances in consumer products (PoHS) in regulations related with restrictions on manufacture, import, export, sale and use of chemicals.

- Larger scope than RoHS and applies not only to EEE but to all goods defined as “consumer”.

- Bans more than 18 substances (e.g. Arsenic, TBBPA, HBCDD (brominated flame retardants))

- Maximum admissible concentration values are also more restrictable than RoHS (e.g. 0,010% for lead and cadmium).

- **Norway wants to encourage EU to take similar steps.**

The RoHS Directive

US Status on RoHS

- **California**

-Adopted EU`s RoHS Directive for the 1st time in 2003 together with the Electronic Waste Reycling Act related with the producer responsability requirer along the lines of the EU`s WEEE Directive (2002/96/EC);

- Implementation on 1st January of 2007;

-Currently applied to Video Display Devices and will apply to lighting equipment

- California RoHS narrower in scope than EU Directive once is only limited to "covered electronic devices";

-Restricts lead, mercury, cadmium and hexavalent chromium but not restricts th use of any brominated flame retardants in "covered electronic devices".

The RoHS Directive

US Status on RoHS

- **New Jersey**

-Adopted e-waste on January 2008;

-New Jersey RoHS scope is applicable to a larger group of products than California
like computers, monitors and televisions ;

-Will get into force in 2010 the Prohibition of sell or offer for sale any new covered elecronic device unless those products comply with EU RoHS Directive 2002/95/EC;

-Dynamic updates with EU revisions

- **Other states – Minnesota**

- e-waste engagement since September 2007;
- From September 2008 is requested to include a statement on allowed values acc. RoHS but not restricts the use of any substances.

Current Status

- RoHS implementation in force since July 2006
- Supply Chain issues e.g. Testing Methods not fully resolved in Europe (IEC 62321)
- Concerns remain over reliability in affected sectors
- Improved materials technologies still evolving
- On-going environmental pressures – REACH, EuP
- Extent of RoHS scope (Report October 2008)
- Transition to exempt sectors until ?2010

Outline

- European Implementation of RoHS
- **RoHS oriented SME European Research Projects**
- LEADOUT Project – Overview & Final Results
- Forthcoming related projects - ELECTROVALUE

Lead-free soldering R&D Overview (2000-2007)

- INNOLOT
  - Harsh environment solders
- COST 531
  - Solder Alloy Properties Database
- IMECAT
  - Assembly, Reliability
- LEADFREE
  - Reliability, SME Demonstration
- PROTIN (in cooperation JEITA, iNEMI, Soldertec)
  - Tin whiskers
- EFSOT
  - Assembly, Environmental

Lead-free soldering R&D Overview (2000-2007)

- **iNEMI**
  - **Assembly, Tin whiskers**
- **JG-PP/JCAA Lead-free Solder Project,**
  - **Defence/aerospace assembly, reliability**
- **IPC SPVC**
  - **SAC alloy composition**
- **SME RoHS Support – GREENROSE, LFS-for-SME's, LEADOUT**
  - **Guidelines, Procedures, life cycle assessment, hand soldering, defects**

making connections

ELFNET - European Lead-Free Soldering Network

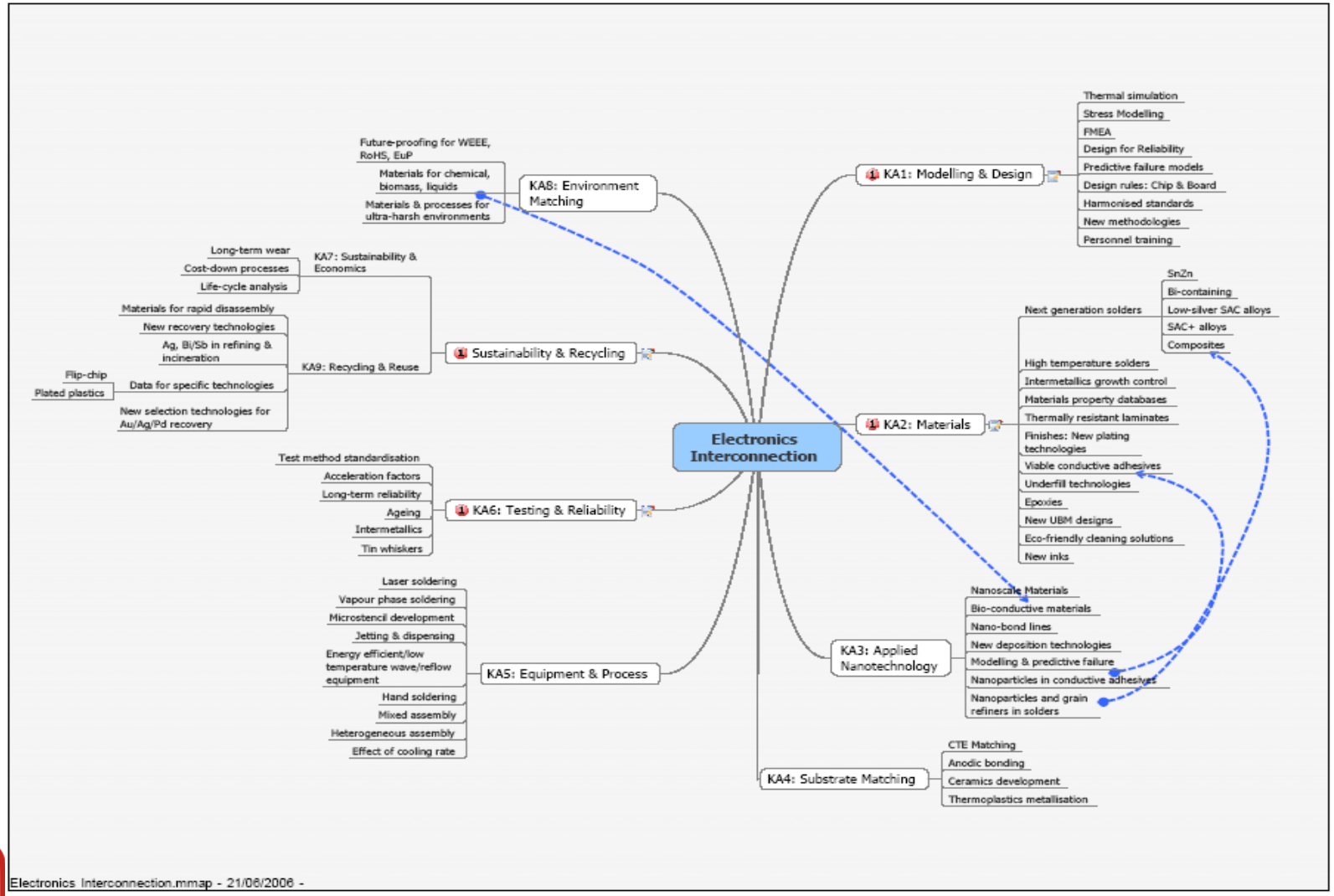
"To urgently coordinate, integrate and optimise

the critical mass of European research in lead-free soldering;

providing pan-European support for implementation of the RoHS Directive

www.europeanleadfree.net

ELFNET roadmaps …Solutions R&D Gaps



ELFNET roadmaps …Solutions R&D Gaps

Solders TEG

- Reliability:
- Temp Effects
- Cost

Secondary issues

- Heterogeneous assembly
- Hand soldering

Components TEG

- Whiskers
- Obsolescence
- High Temp Applications:

Secondary issues

- Intermetalics (IMC's)

Assembly TEG

- Reliability data
- Stability of Materials
- Materials declaration

Secondary issues

- Sn whiskers
- Repair capability.

Recycling TEG

- Labelling
- Eco vs Dis assy
- Green markings

Secondary issues

- Re-usable parts,
- Test standards
- Mixed Solder assemblies

Reliability TEG

- Test methods
- Modelling
- Harsh environments

Secondary issues

- materials declaration,
- mixed materials assembly
- recycled reused parts
- alloys properties
- Hand soldering
- Complex boards.

GreenRoSE

“Removal of Hazardous Substances in Electronics: Processes and Techniques f

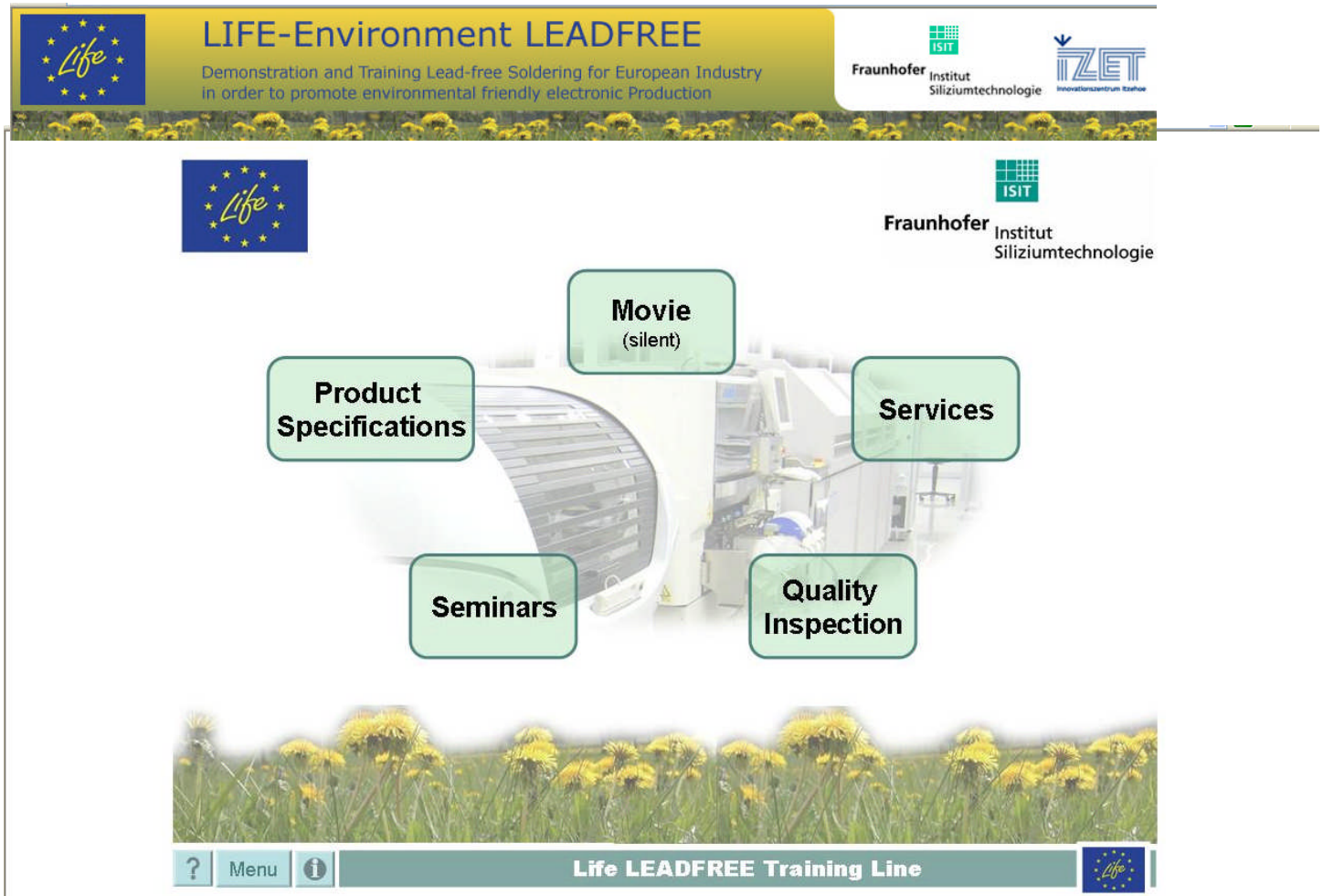
Deliverables:

- **Priority Hazards in Electronics Report**
- **Substitution of Priority Hazards**
- **Guidelines and check lists for RoHS Implementation**
- **Pilot line for SME application**

HORIZONTAL ACTIVITIES INVOLVING SMEs

Detailed information available at:

www.green-rose.info



www.life-leadfree.de

Outline

- European Implementation of RoHS
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- **LEADOUT Project – Overview & Final Results**
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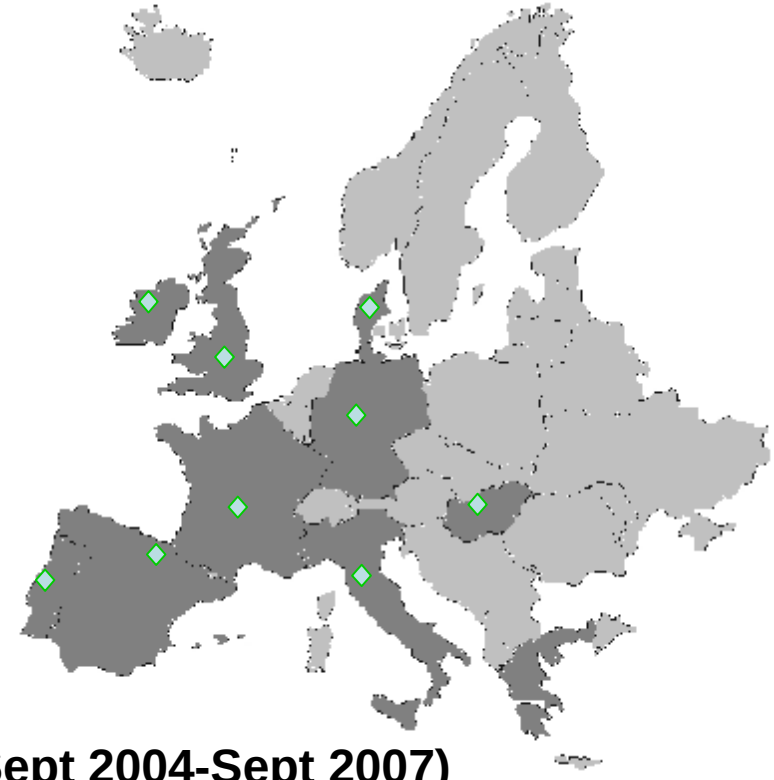
LEADOUT

Low Cost Lead-Free Soldering Technology to Improve Competitiveness of European SME

29 Partners
9 European countries
10 Industrial Associations
15 SME
4 RTDs



Collective Research

HORIZONTAL ACTIVITIES INVOLVING SMEs

Duration: **36 months (Sept 2004-Sept 2007)**

Project Background & Motivation

RECENT EUROPEAN DIRECTIVES
Hazardous Products - RoHS (2002/95/EC)
Electronic Equipment End of Life - WEEE (2002/96/EC)

1st July 2006

- SME LACK OF KNOWLEDGE AND LOW LEVEL OF LFS IMPLEMENTATION
- LACK OF RESEARCH WORK REGARDING LOW SCALE PRODUCTION (SMALL SERIES)
- EUROPEAN BENCHMARKING OF LFS PROCESS

Strategic Objectives

- Development/implementation of low cost lead-free soldering processes to support SMEs in meet the EU directives
- Establishment of process quality standards, reduction of defect rates, improve reliability and therefore competitiveness
- Improve Health and Safety awareness and pollution prevention

The Project

LEADOUT consisted of:

- **6 inter-linked work-packages**
- **29 partners (9 countries)**
- **28 separate tasks**
- **39 separate deliverables**
- **The Directive is in force, electronics assemblers are now in compliance**

Main Public Project Deliverables

- SME Lead-Free Soldering Technology Implementation Recommendation Guide
- Photolibrary Inspection Guide
- Environmental Impact Guide
- Training Lead-Free Course
- Lead-Free Process Benchmarking Programme

Activities & Results

1. Communication – Awareness and Dissemination
2. Soldering & Reliability Assessment
3. Health & Safety and Environmental Evaluation
4. Training
5. Process Benchmarking

1. Communication

Objectives

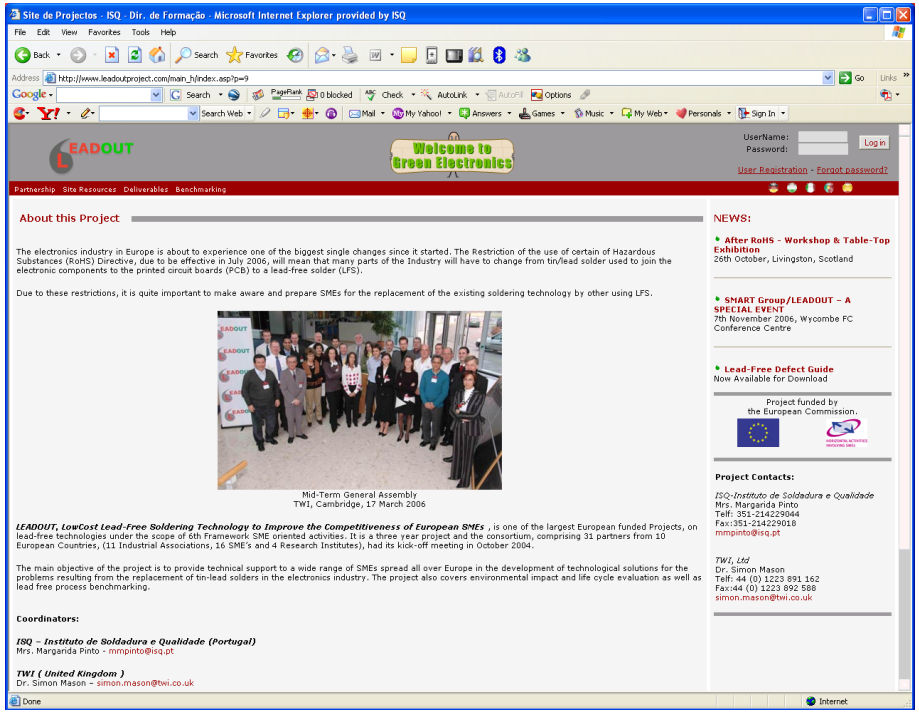
Information exchange, Awareness & Dissemination

Activities Carried Out

- ❑ **Website Development**
- ❑ **Project Newsletters & Periodic Publications**
- ❑ **Industrial questionnaires & Information Seminars**

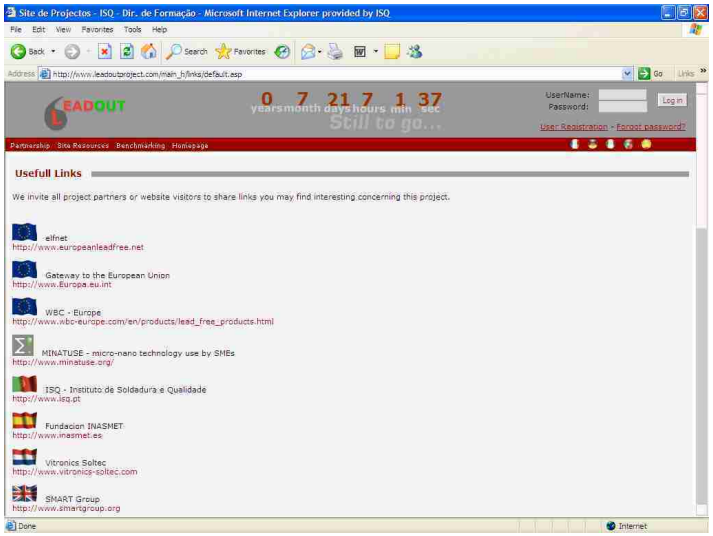
1. Communication

Information Exchange



PROJECT Web Site

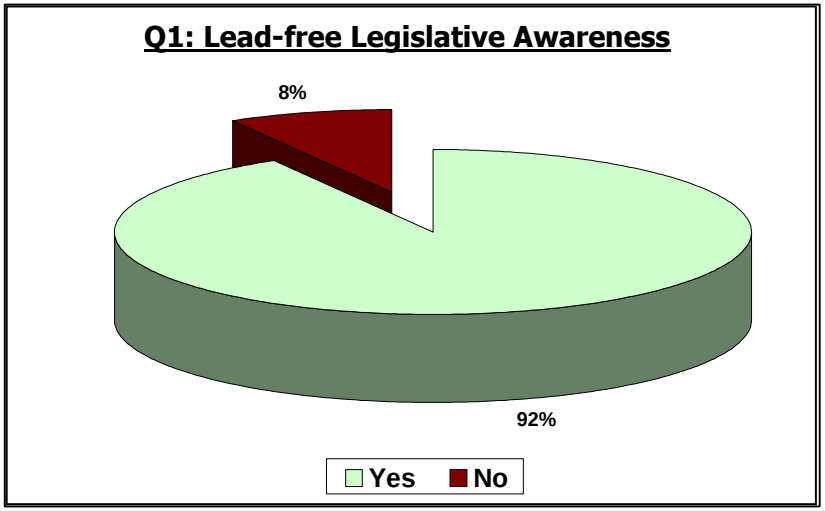
WWW.LEADOUTPROJECT.COM



Site Languages: English, Spanish, German, Hungarian, Portuguese, Italian

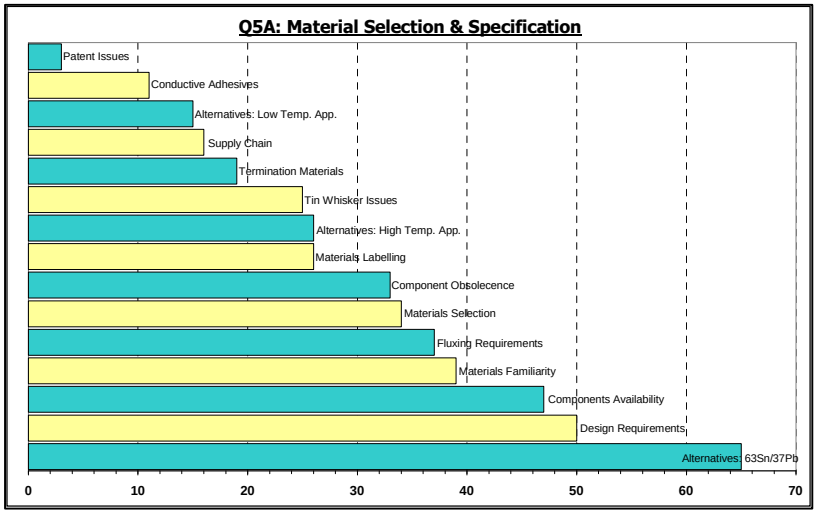
1. Communication

Information Exchange



LFS IMPLEMENTATION SURVEY

LOUT/TWI/DEL-14



Detailed information on D1.1.3 report

1. Communication

Project Newsletters

LEADOUT

Kostengünstige bleifreie Löttechnik zur Verbesserung der Wettbewerbsfähigkeit der KMUs in Europa

Collective Research Projekt im 6. Forschungsrahmenprogramm der Europäischen Union

NEWSLETTER©

Ausgabe 1 / Juli 2005

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Vorwort

Die Elektronikindustrie in Europa ist seit Beginn ihrer Entstehung im Begriff, eine der weitreichendsten Reglementierungen durch den Europäischen Gesetzgeber zu erleben.
Am 13. Februar 2003 haben Europäisches Parlament und Rat zwei Richtlinien verabschiedet (WEEE und RoHS), welche die Verantwortungsbereiche der Hersteller und Importeure von elektronischen Produkten bedeutend erweitern.

Die Richtlinie zur Einschränkung des Einsatzes bestimmter Schadstoffe (RoHS), die am 1. Juli 2006 in Kraft tritt, wird bedeuten, dass viele Sparten der Industrie bei dem beim Fügen und der Bestückung von Leiterplatten mit Elektronikbauteilen bisher verwendeten Zinn-/Bleilote auf bleifreie Lote umstellen müssen. Diese Umstellung erfordert eine Restrukturierung der entscheidenden, aufeinander abgestimmten Prozesse im Unternehmen und der gesamten Lieferkette, stellt jedoch nur einen Teil der Gesamtproblematik dar. Zum einen sind über die Hälfte der Bauteile, die sich derzeit im Prozeß der Zulieferkette befinden, (noch) nicht richtlinienkonform (d.h. noch mit hohen Bleianteilen hergestellt), zum anderen ist zu beachten, dass Bauteile, die im Bleifrei-Prozess verarbeitet werden sollen, auch für dort höhere Temperaturen geeignet sein müssen als bisher.
Im Reflow-Löt-bereich geht die Haupttendenz zur Anwendung von Zinn-Silber-Kupfer-Loten mit einem Schmelzpunkt von 217 °C. Im Wellenlötbereich gibt es Zinn-Kupfer-Legierungen, deren Schmelzpunkt 10 °C höher ist, wodurch die Prozessfenster bei den bleifreien Lötprozessen kleiner als bisher üblich werden mit den sich daraus ergebenden gesteigerten Planungsanforderungen.

Wofür steht RoHS und WEEE?

RoHS ist die Abkürzung für die

- RICHTLINIE 2002/95/EG DES EUROPÄISCHEN PARLAMENTS UND DES RATES zur Beschränkung der Verwendung bestimmter gefährlicher Stoffe in elektrischen und elektronischen Geräten = Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment.

LEADOUT

Low-Cost Lead-Free Soldering Technology to Improve the Competitiveness of European SMEs

Collective Research Project in the 6th Outline Research Programme of the European Union

NEWSLETTER©

Issue 2 / March 2006

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Opening Note: 1st Year LEADOUT Review

There are less than five months to go before the implementation of the RoHS (Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment) Directive across the European Community. From 1 July 2006 all electrical and electronic products put onto the market in Europe will have to comply with this legislation. The single biggest effect of the directive will be to outlaw the use of lead-based solders for all assemblies with only a few exceptions.

Most large manufacturers have been planning and preparing for this change for some time, however many SMEs across Europe are only now beginning to gear up to the challenge of the next few months.
A recent Leadout survey showed that SMEs across Europe know about the legislation and its impact, but haven't yet addressed how they will implement changes to their procedures to bring them into compliance.

Key issues
The change to lead-free assembling gives rise a number of challenges, these include:

- Materials selection and compatibility
- Processing and equipment capability
- Manufacturing yields and throughput
- Functional performance
- Establishment of reliability performance and baselines
- Health and safety

The key change in going from leaded to lead-free soldering and central theme through all these issues is that of complexity. The vast majority of manufacturers and assemblers have historically had to deal with tin/lead alloys as the dominant materials for pcb finishes, component finishes and solders. Variations in performance could be traced to assembly and processing procedures and how close (or far) the product had been to an optimum manufacturing cycle.

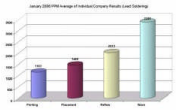
1. Communication

Project Publications

LEADOUT on the Road

Benchmarking of the Soldering Process - PPM Study and Defects

One of the main objectives of the LEADOUT Project is to provide the benchmarking of the Lead-Free soldering process, in order to improve the European competitiveness of the electrical and electronic industry, especially SMEs.



Based on the UK project started by SMART Group, the **Parts Per Million** (PPM) Opportunities, also known as **Defects Per Million Opportunities** (DPMO) is a method to measure the amount of defects occurring on a Printed Circuit Board (PCB).

The LEADOUT Research Institutes partners are assisting the SME companies on how to collect comparable data on their own manufacturing processes. The data is collected in each stage of the process (Printing, Placement, Reflow and Wave). The generated data are being gathered and treated by the Research Institutes to give overall figures for the PPM levels currently being achieved using leaded solders, and how those levels change during and after the conversion to lead-free processing.

Until now this benchmarking programme is limited to the assemblers within the Project, 10 in total, who are currently using Lead soldering. All the results are available and are being posted and updated, each month, in the Project Website: www.leadoutproject.com

The types of defects that occur are available at the "Defect of the Month" at the project website.

Every month it is available for information a new kind of defect, presenting its main characteristics and nature, allowing a brief knowledge of the defects that occur in the soldering process.

Courtesy of Mr. Bob Willis

The LEADOUT Project Benchmarking is now open to external companies. Therefore, we are pleased to welcome new companies to be involved in the LEADOUT benchmarking programme. So, if your company is interested in join us, please contact the responsible for the PPM process on the LEADOUT Project:

Mr. Rolim Carmo
rdcarmo@isq.pt

Please be aware that the reliability of this study increases with the number of participants, offering benefits to all the companies involved in it. The data provided is completely confidential.

Do not forget to visit us at: www.leadoutproject.com

Lead-free Soldering Trials – Soldering Results

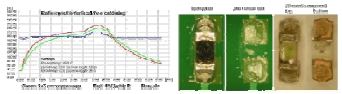
In the work package n° "Lead-free Technology Industrial Implementation" (WP6 of the LEADOUT Project, soldering trials were performed at industrial sites by the R&D and the shop-floor operators' in order to have a close control and to improve the transfer of the know-how of the R&D. Those circuits were selected by ISQ, the Hungarian University of Technology and Economics in collaboration with SZEM and Ericsson Ltd's (the Hungarian R&D and SMEs, respectively) for fabrication using both leaded and lead-free soldering technologies.

SMEs LEADOUT board, see in the figure on the left and two diagonally counterbored boards of the SMEs were fabricated at each site using the leaded technology as a baseline and the new lead-free technology, which was developed in the frame of WP2, on another 25 samples. The fabrication of the boards was monitored by electrical tests as well as optical inspection, and reliability tests were completed on them.

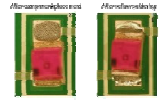
Quality evaluation of solder joints was carried out in the factories at different aspects like applied materials and processing technology. The activity of ISQ is focused on the following items:

- process monitoring strategy based on optical inspection was developed and applied;
- short test equipment was developed and implemented. Therefore tests were carried out:
  - tool bend test, shock test for both the effect of thermal type and rigidity on solder joints reliability
  - process and the quality of the solder joints;
  - life-time test methods were studied.

Soldering trials resulted in the main conclusion that when optimized temperature profile (left figure) were applied, the lead-free soldered joints were strong, noisy more, especially at the small (0402) component sizes, the soft were torn from the board, the joints survived (right figure).



It was found that the self-aligning property of lead-free soldering is much better than it was expected by some technical papers. The higher surface tension and lower wettability of lead-free solders were help to push the component into the correct position, as it is illustrated in the figure on the right. When the solder melts nearly, at first it forms a liquid bump on the pad under the terminal, the bump lifts the end of the component and it slides towards the correct position.



Do not forget to visit us at: www.leadoutproject.com

Impact of emissions from soldering processes on occupational workers' Health.

Different industries have for several years been subject to increasing legislative requirements towards the development of "Cleaning Technologies". This is the situation of electric and electronic industries and the imperative implementation of lead-free soldering processes. This change has been caused by the European Directive 2002/95/EC RoHS. According to it, the use of lead, mercury, hexavalent chromium, cadmium and others will be banned from next July 2006.

Although the main objective of the LEADOUT project is to provide technical support to the European electric and electronic SMEs during the removal and change of lead from the tin/lead solder used to join electronic components to the PCB, the principal concerns of this project should be taken into account:

- The importance of the potential environmental impact (like lead waste from the manufacturing process and the disposal of lead containing electronic equipments at the end-of-life could contaminate the landfills and subsequently, the Environment) and,
- The relevance of the social issues (it is mandatory the maintenance and preservation of the involved soldering process worker's health)

Removal of this source of contamination will have, therefore, a considerable positive impact in terms of quality of the working conditions and, also, in the environment as a whole. Effectively, the threat in human health by lead accumulation in the body due to the occupational exposure is becoming a greater concern. The continuous inhalation of gases containing lead over finite excess chronic intoxication affecting mainly the Central Neuronal and Peripheral Neuronal Systems. Also anaemia and Renal and Cardiovascular problems can be produced.

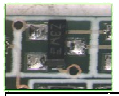
Although the use of lead in the electronic industry seems to be minimal, the contamination potential for lead exposure during soldering processes through the inhalation of lead vapours is the reason to perform generated emissions measurements. The aim is, therefore, to determine the existence of hazardous substances susceptible of to be inhalated by the workers at the assembling companies that use tin-lead alloys and, after this, to make a comparison to the emissions from the industries that use lead-free solders.

With this aim and within the framework of the LEADOUT project, several measurements of the chemical agents emissions generated during the soldering process have been performed. Also, a further analysis and evaluation of the potential hazardous characteristics for the workers' health have been made. As it has been mentioned, at the moment, measurements at different companies participating in the LEADOUT project have been carried out. These enterprises used until now, tin-lead based pastes and solders. Once lead free processes (mainly wave and reflow) are implemented and running at the optimal conditions, measurements of emissions using lead-free solders will be done.

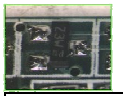
Research Centres participating in this LEADOUT Project are in close contact with different SMEs participating in the project and made the measurements during a habitual work-day. For this purpose, sampling pumps (see photos 1 and 2) are put on the even worker close to the breathing zone. The usual activity and the movement of worker at the soldering facility are allowed by the pump that gets samples of the breathed air by workers during the several tasks that they are realizing.

Solder Joint Inspection – The Photolibrary

One of the key outputs from LEADOUT is a searchable photo-inspection library of solder joint images, taken during assembly and reliability trials carried out in the project. The photolibrary will be of particular use to company inspection and quality staff as a source of reference, training and technical material. Importantly, the images have associated joint information such as the solder alloy, assembly method, component/joint type, pcb board finish and where available, component finish. This extra data allows the library to be searchable, so that users can easily material and process combinations and locate the relevant volumes. In addition, because the assembly trials were designed to manufacture products with both lead-free and tin/lead solder, users of the library are also able to directly compare similar joints made with the different alloys under similar magnification and lighting conditions. Soldering defects will also be included, and where possible, reliability data related to the joints in the images will be stated. Below are examples of photolibrary content:



A BGT package with a tin/lead termination finish, reflowed with SnAgCu alloy under a tin/lead (eutectic) profile



A BGT package with a tin/lead termination finish, reflowed with tin/lead alloy under a tin/lead (eutectic) profile

A BGA package made soldered with tin/copper/nickel alloy balls on OSP coated pcb

A leaded device with tin/lead plated leads made soldered with tin/copper/nickel alloy balls on immersion gold/electroless nickel pcb

The photolibrary images will start to become available later this year via the Leadout website at: www.leadoutproject.com

Issue: December 2006

Lead-free Assembly Course – Conventional and Virtual Training Course for SMEs

One of the main deliverables of the LEADOUT Project is the production of training courses covering the different technical aspects of the lead-free soldering process focused on SMEs requirements. It was developed two formats of training courses, conventional based on PowerPoint Presentations and one other, applied for e-learning using the LEADOUT website and an e-learning platform for on-line training.

The specific objectives of the *Lead-free Assembly Course* are to give an adequate training in printed circuit board (PCB) manufacturing methods and materials, with a particular focus on lead-free technology. The two modules formats will allow the SMEs to select the most adequate training model to be used in-house accordingly with staff availability and thus offering a more flexible training accordingly with their requirements.

The target groups for the training modules developed are mainly concerned with production engineers and operators.

The *Lead-free Assembly Course* contains 5 independent Modules:

- **Module 1** - Solder paste printing and stencil handling
- **Module 2** - Inspection of lead-free joints
- **Module 3** - Lead-free plating finishes
- **Module 4** - Hand soldering and rework
- **Module 5** - Reflow and wave soldering and temperature profiling

E-learning Format

In the e-learning course at the end of each lesson there is an assessment questionnaire. For an user to continue to the following lesson a defined score has to be reached otherwise the user has to repeat the lesson. This minimum score is not always the same nor directly dependent of the number and type of questions. At the e-learning platform is also available a course report in which a user can easily check his progress on the course and achieved results.

Conventional Format

If you are interested in further information or you have any question about the LEADOUT Training Courses, do not hesitate to contact Marta Freitas at mafreitas@isq.pt.

For further information about the LEADOUT project please visit the website at www.leadoutproject.com.

1. Communication

Project Seminars

2. Soldering & Reliability Assessment

Objectives

Research on Lead-Free Technology Solutions & Industrial Implementation Guide

Activities Carried Out

- ❑ **Lead & Lead-Free Soldering Trials– Industrial and LEADOUT Test Board**
- ❑ **Boards Characterisation & Reliability testing**
- ❑ **Photolibrary Development**
- ❑ **Virtual Design Simulations – Design for Reliability**

Soldering Trials

- 8 companies contributed with real products
- Commercial Solders and Pastes:

Leaded: 63Sn/37Pb

60Sn/40Pb

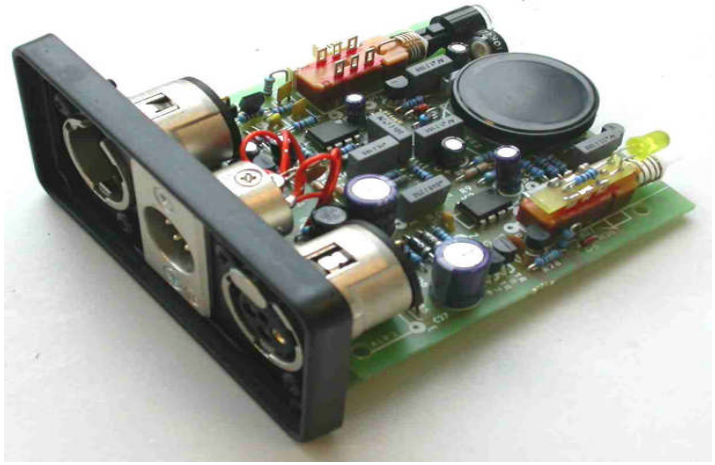
62Sn/36Pb/2Ag

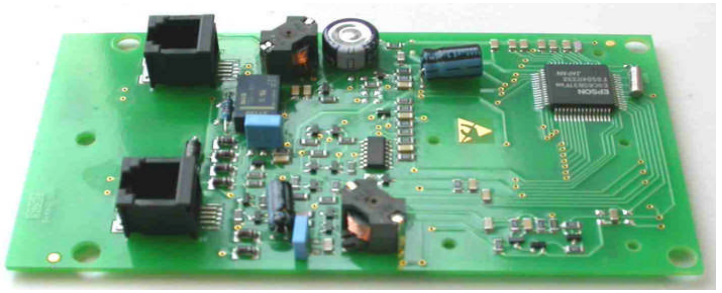
Lead-free: Sn/Cu/Ni(SN100C)

96.6Sn/3Ag/0.5Cu

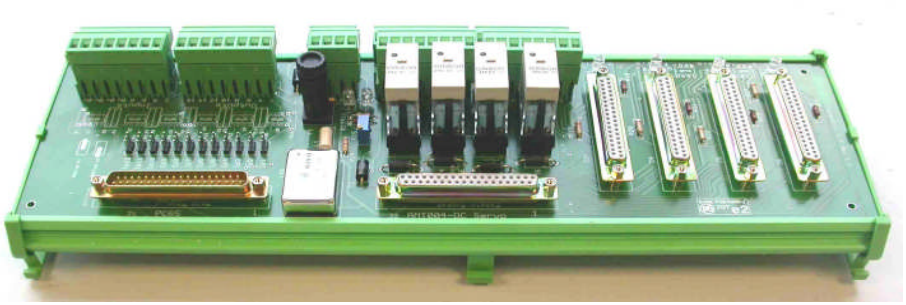
95.5Sn/3.8Ag/0.7Cu

Sn/Ag/Cu/Bi (SACX)





Soldering Trials



Soldering Processes:

Reflow

Wave

Hand

Assembly Type:

SMD – Surface Mount Devices

Through-hole

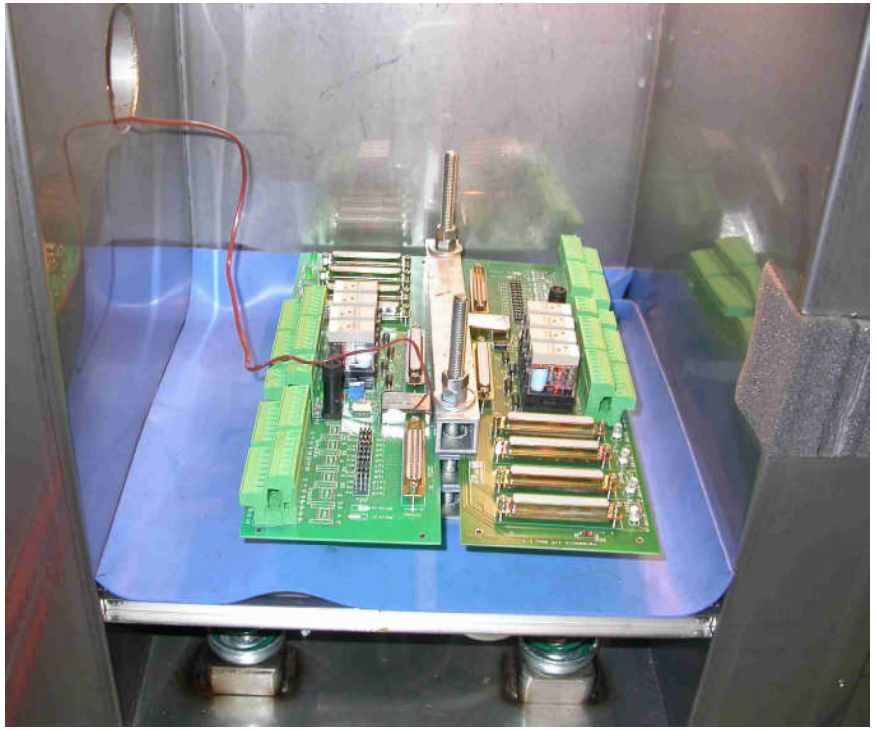
Temperatures:

250ºC (Wave, Lead)

255 – 270ºC (Wave, Lead-free)

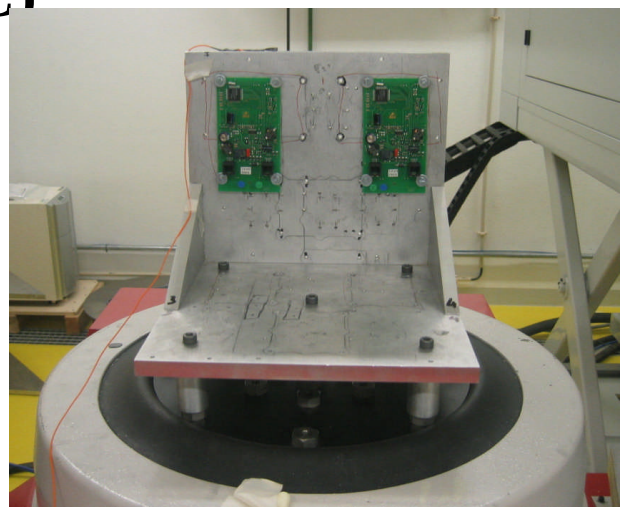
2. Soldering & Reliability Assessment

Reliability Testing



Reliability Tests Data

- Low temperature storage (72h; -40ºC)
- High temperature storage (7 e 28 days; 100ºC)
- Thermal cycling (3000 e 6000h; 0 – 100ºC)
- Thermal shock (5 cycles; (-40) – 100ºC)
- Vibration (30 min on x, y and z)
- Shear test (10s; 10N)



Reliability Tests-Some results

Visual inspection

After reliability testing:

- **Low temperature storage**
  33% Sn/Pb and 0% of the LF boards did not pass the functional tests
  No visible defects

- **High temperature storage**
  50% Sn/Pb and 27% of the LF boards did not pass the functional tests
  Component failure

Reliability Tests-some results

- **Thermal cycling**

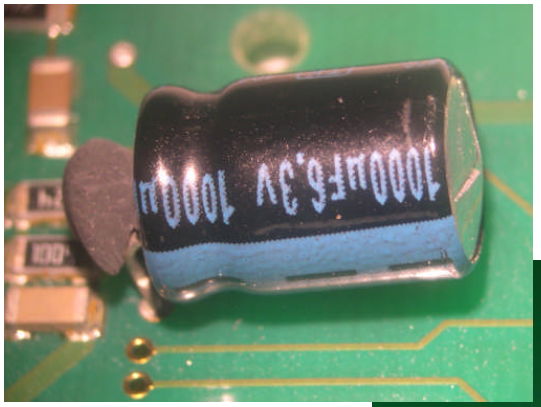
  59% Sn/Pb and 49% of the LF boards did not pass the functional tests

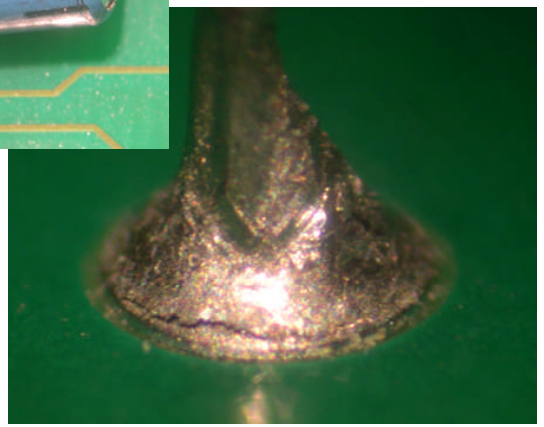
  Component failure

  Cracks on the joints

  Damaged components

  Degradation





Reliability Tests-Some results

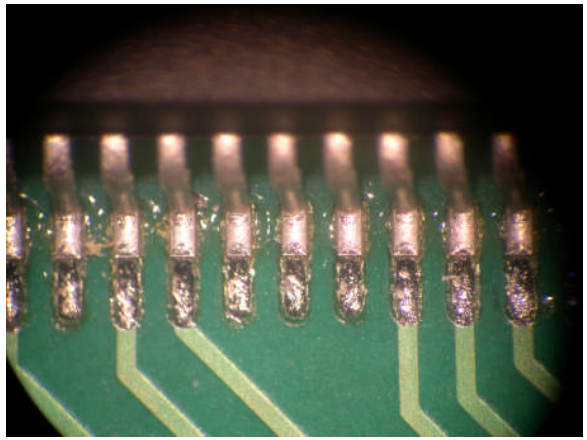
- **Thermal shock**

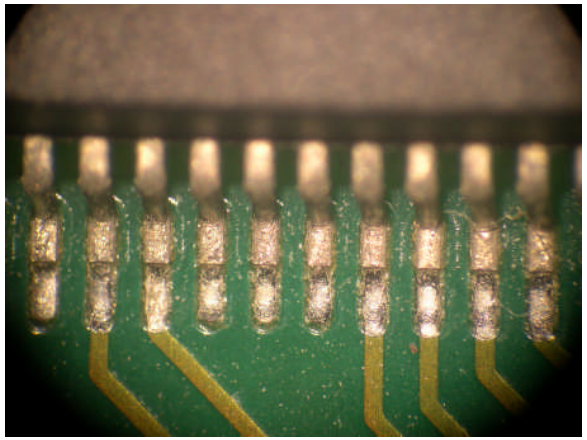
  0% Sn/Pb and 11% of the LF boards did not pass the functional tests

  No visible defects

- **Vibration**

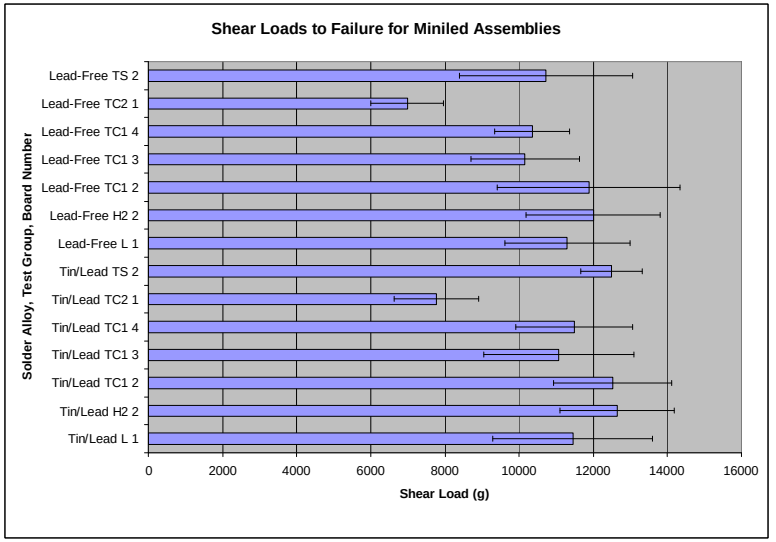
  All boards passed the functional tests

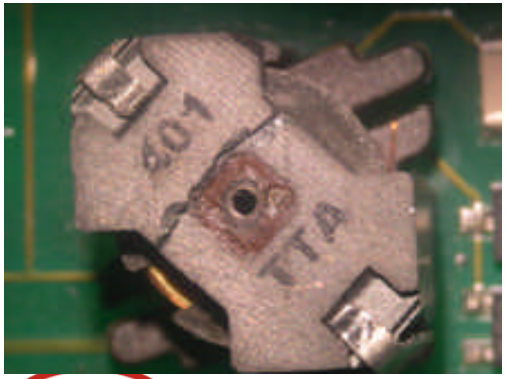


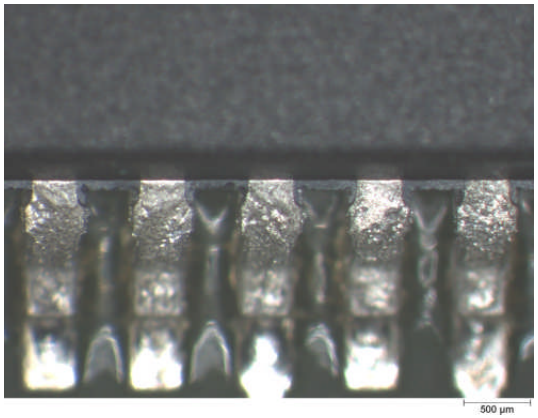


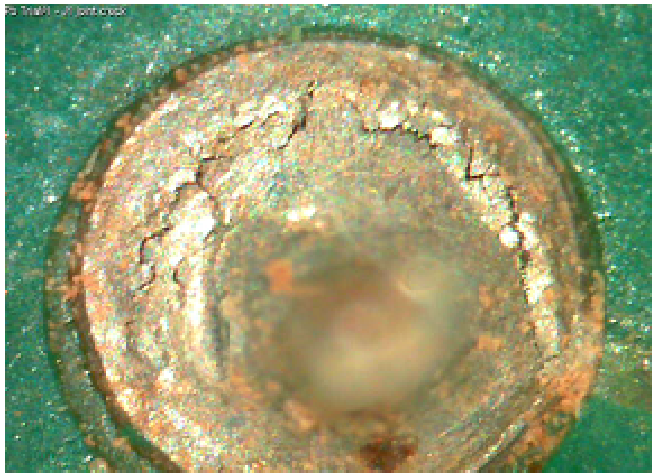
2. Soldering & Reliability Assessment
Reliability Testing -Conclusions

- Lead-free solders performed equal or better than tin-lead alloys.
- The reliability of surface mount joints exceeded that of through-hole joints.
- Visual inspection remained an adequate indicator of solder joint quality.



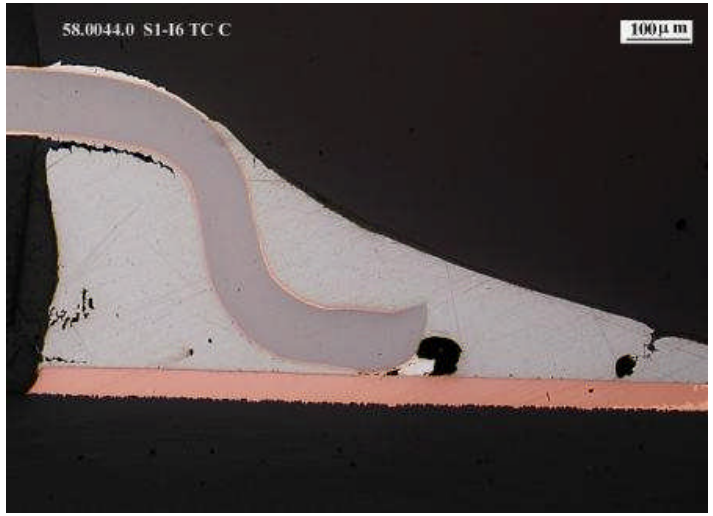


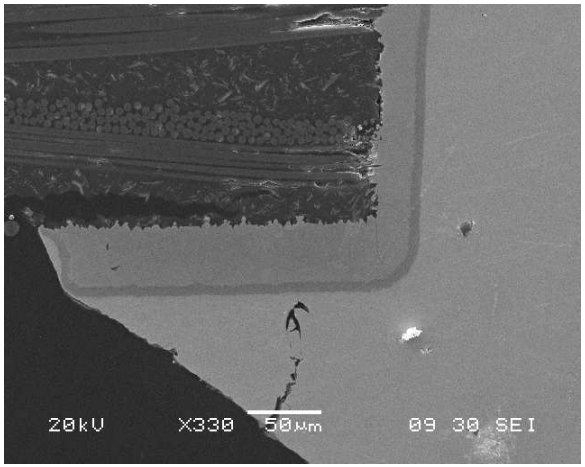




2. Soldering & Reliability Assessment

Industrial Boards Characterisation





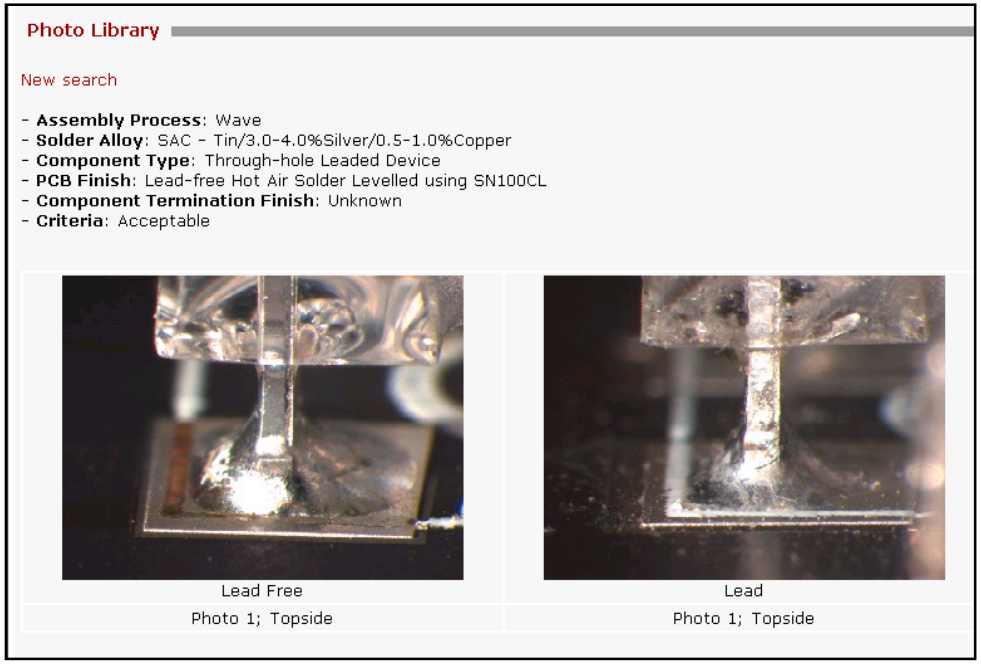
In general the Lead-free joints showed good performance on the reliability tests carried out.

The surface mount joints are less degraded than the through-hole ones for majority of the tests

Inspection Photolibrary

- **Database of solder joint images that allows the comparison between Lead and Lead-free solders**

- **Resulted from the industrial results obtained by the partners**



2. Soldering & Reliability Assessment

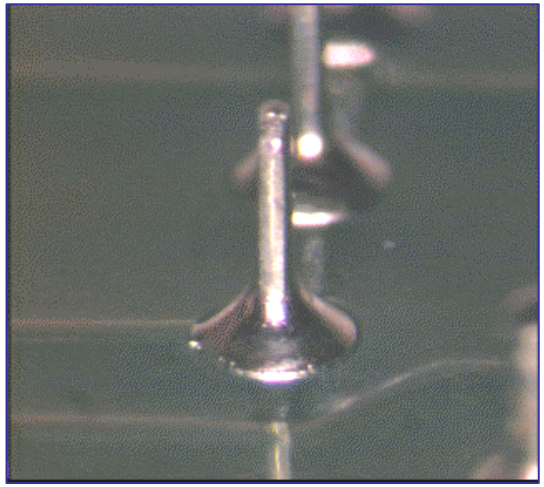
Photolibrary

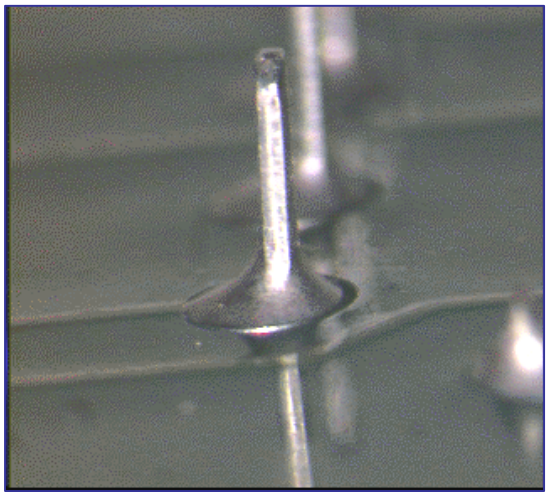
1. Searchable inspection guide showing acceptable lead-free solder joints with material, geometry and process information
   - Comparative tin/lead images are also available with similar magnification, angle, lighting etc.
   - Currently approx. 220 images
2. Soldering defects
3. Miscellaneous
   - Currently approx. 220 images

2. Soldering & Reliability Assessment

Photolibrary

- Searchable by:
  - Type of paste
  - Process
  - Type of component
  - Board coating
  - Component plating

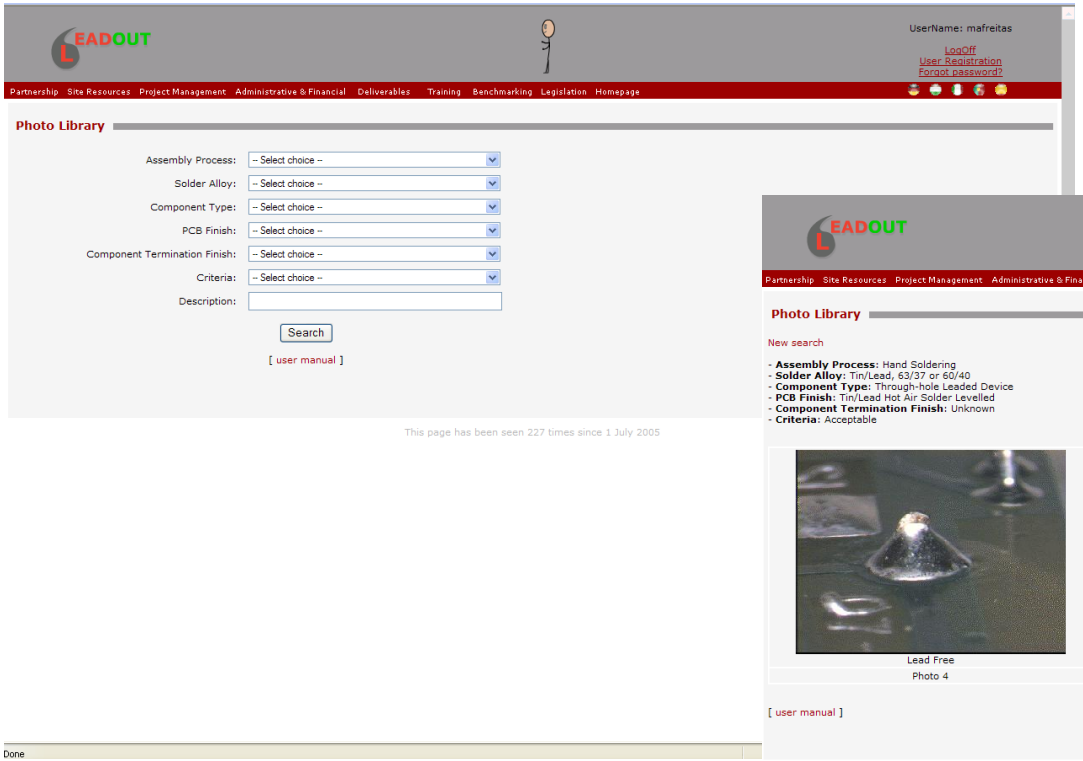


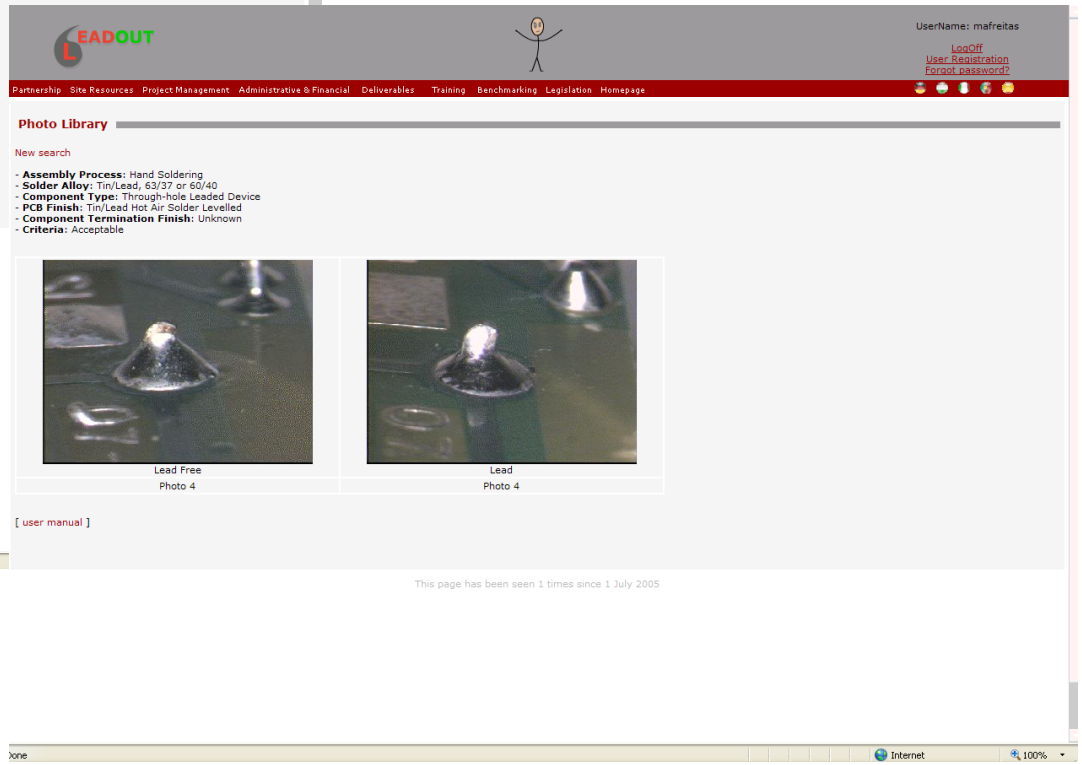


- Acessable through: www.leadoutproject.com

2. Soldering & Reliability Assessment

Photolibrary





3. Health & Safety and Environmental Evaluation

Objectives

Environmental Assessment of Lead-Free Process and Solders

Activities Carried Out

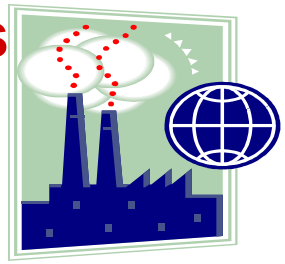
- **Laboratory Environmental Impact Studies & Industrial Planning and Methodology**
- **LCA of Wave & Reflow Soldering Process**
- **Environmental Industrial Measurements (Occupational Health, Fumes assessment and Leaching tests)**

3. Health & Safety and Environmental Evaluation

Industrial Measurements

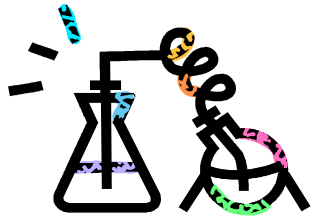
Environmental Assessment of Processes - Analysis of the environmental parameters and occupational exposure in lead and lead free soldering – Quantitative Analysis

Fume emissions tes



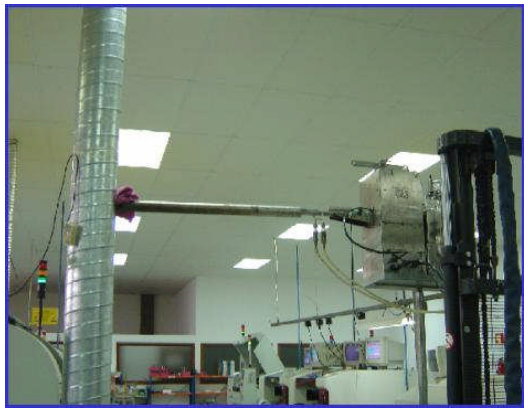
Occupational Exposure

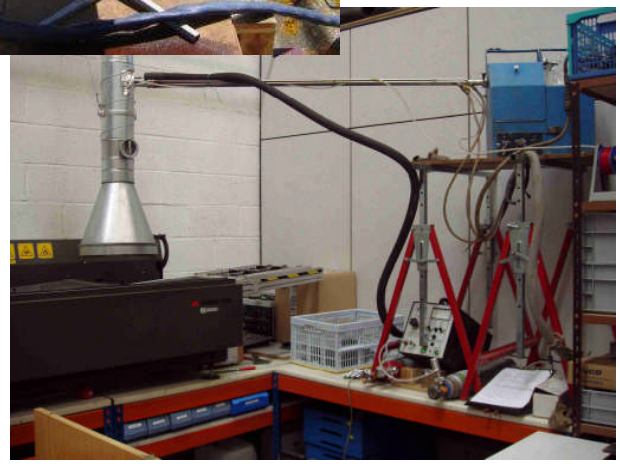
Leaching



3. Health & Safety and Environmental Evaluation

Environmental Measurements





Detailed information on D3.4.1 report
Fume emission lab tests on D2.4.1 report

4. Training

Objectives

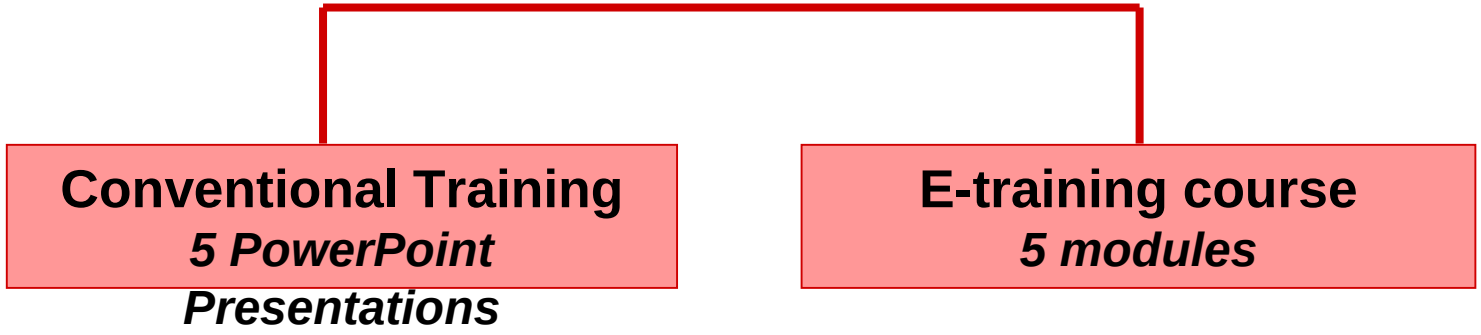
Training material and courses for Industrial use

Activities Carried Out

- ❑ **Five LFS modules**
- ❑ **Conventional training material**
- ❑ **E-learning course in development and implementation**

Training on Lead-free Soldering

to help the transition to lead-free soldering at SMEs



4. Training

LEAD-FREE ASSEMBLY COURSE

Module 1. Solder Paste Printing and Stencil Handling

Module 2. Reflow and Wave Soldering Temperature Profiling

Module 3. Lead-Free Plating Finishes

Module 4. Hand Soldering and Rework

Module 5. Solder Joint Visual Inspection

4. Training

Conventional Training

LEADOUT

HORIZONTAL ACTIVITIES INVOLVING SMEs

Welcome to the *LEADOUT* Lead-Free Assembly Training Course

Module 5

Solder Joints Visual Inspection

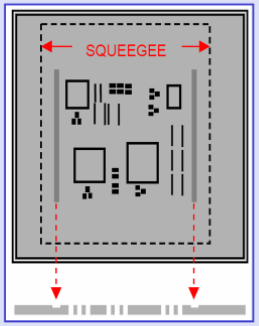
Introduction

LEADOUT

Tips for Maximizing Stencil Life

HORIZONTAL ACTIVITIES INVOLVING SMEs

Tips for maximizing stencil life:
- Proper training & work instructions
- Good board support
- Back-etch relief for surface irregularities
- Proper cleaning and drying after use
- Use of stencil wear indicators:
  - Recess etched strokes - 1 mil
  - On squeegee side
  - Outside print area, inside squeegee area

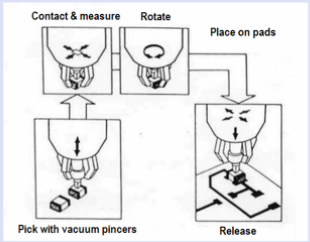


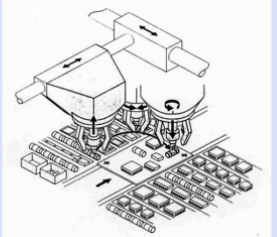
LEADOUT

Placement methods and process sequences

HORIZONTAL ACTIVITIES INVOLVING SMEs

SMT pick-and-place head and machine

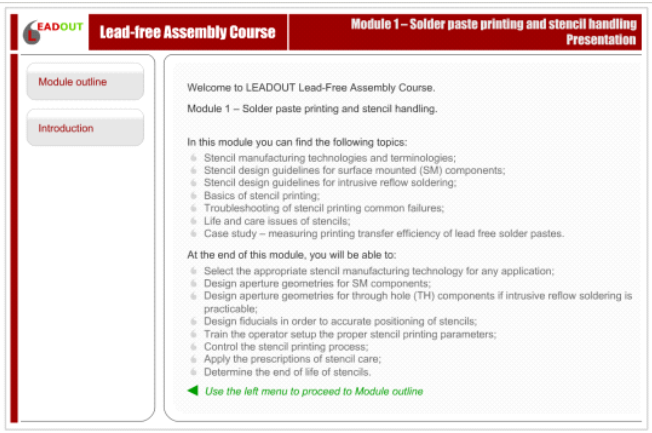


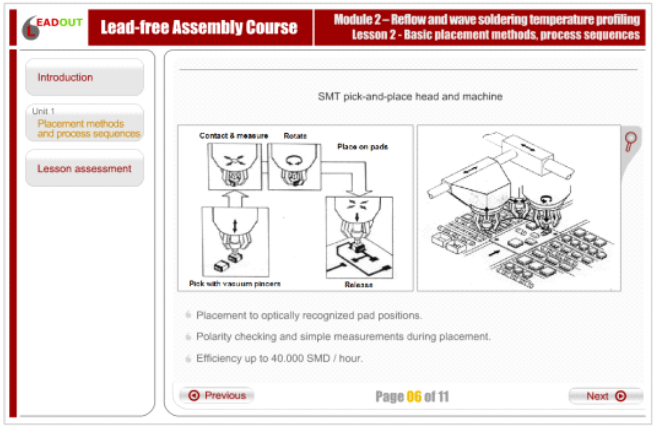


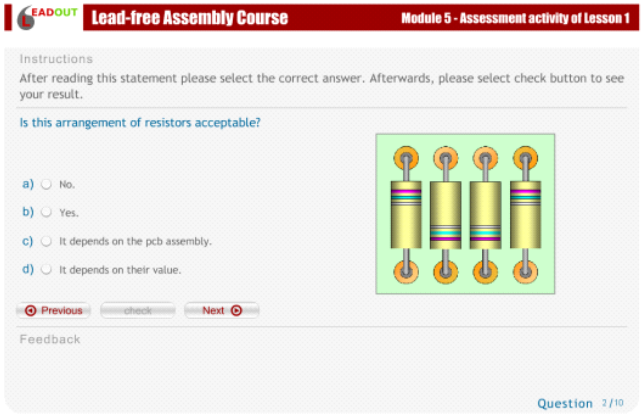
Placement to optically recognized pad positions.
Polarity checking and simple measurements during placement.
Efficiency up to 40.000 SMD / hour.

4. Training

E-Training







Detailed information on D4.2.2 report

4. Training

Both formats are available at LEADOUT website free of charge; Make registration at

www.leadoutproject.com

5. Process Benchmarking

Objectives

Monitor and evaluation of the project performance in terms of Technology and Benchmarking (PPM Programme)

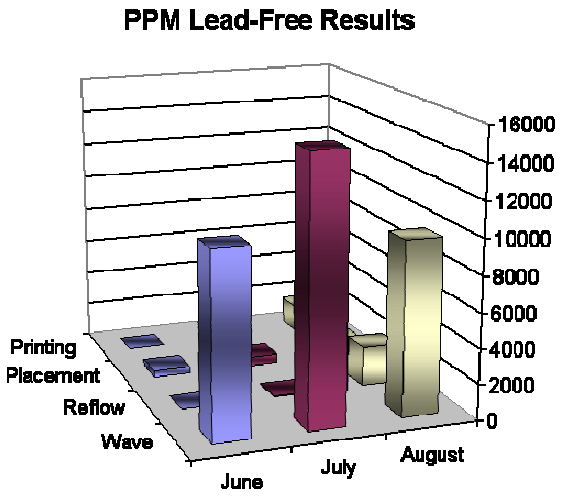
Activities Carried Out

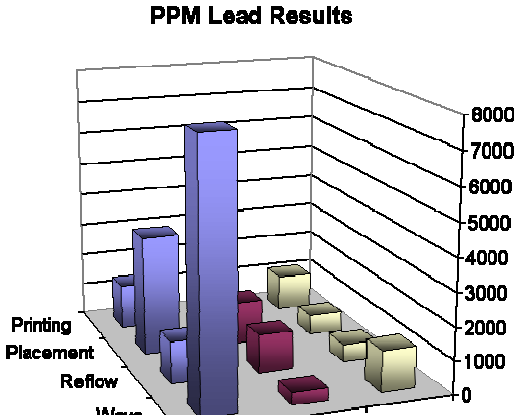
- ❑ **PPM Gathering and data Analysis**
- ❑ **Website Update and Monitoring**

5. Project Benchmarking

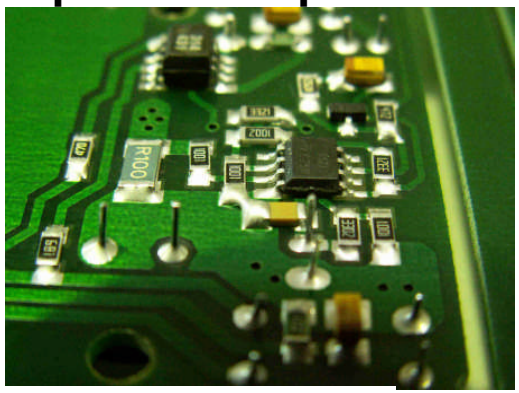
PPM Results

Monthly published at the Web site

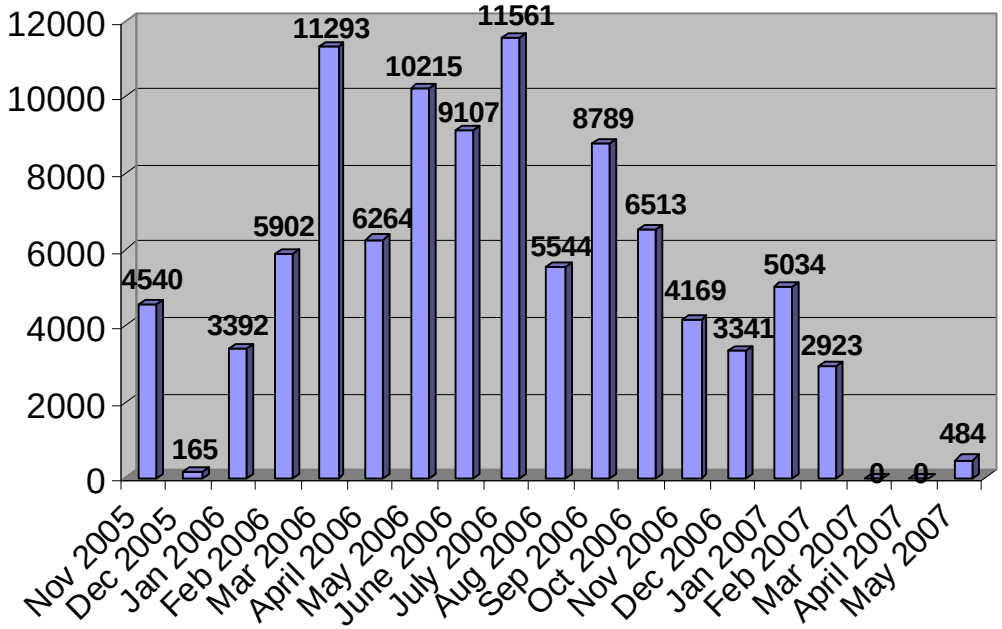




Open Participation



Wave - Nov 2005 to May 2007



Project General Conclusions

- There were no major dificulties in the transition to the lead-free soldering, in the SMEs production, except for the Wave soldering process.

- In terms of solders, only one solder with corrosion inhibitors used for wave soldering presented more defects.

- The defects and anomalies found (voids and pad lifting) are usually due to process parameters, like poor pre-heating and inadequate thermal profiling.

- After the reliability tests, most of the boards have passed the functionality tests, except for the thermal cycling ones. The SMD performed better than the through-hole ones.

Project General Conclusions

- **The cracks on the through-hole joints are away from the interface, do not propagated too far in the joint and follow an intergranular fracture mode. Thus, leading to a good connection between solder and pad in the lead and lead-free joints.**

- **Most of the defects found can be mitigated and should not compromise the integrity and functionality of the products.**

- **It can be concluded, for the industrial boards tested in the project, that the degradation on both types of solder is similar and the lead-free boards performed equally or better that the lead ones.**

Project General Conclusions

- Environmental and Occupational health limits were accomplished for lead and lead-free soldering.

- Filters and extraction systems should be carefully selected based on solder paste used (e.g.Rosin based fluxes; cored solder wires)

- Reflow process - SAC solders have a higher environmental impact over the life cycle in respect to SnPbAg solders. This impact is closely associated to the use of silver. The content of silver in SAC solders should be limited to 3% in order to limit the environmental loss respect to SnPbAg solder.

Project General Conclusions

- **WAVE process - the impacts of Lead-free solder are lower than the SnPb solders. Therefore, Lead-free solders in Wave soldering process present very clear benefits comparing to SnPb solders.**

- **Environmental evaluation helped SME to implement ISO 14001 at the pilot SMEs**

- **The project benchmarking programme revealed as an important tool to enhance the process quality control and the quality of solder joints**

ACKNOWLEDGMENTS

ISQ is grateful to all the ones that had carried out the work herewith presented, namely:

- Simon Mason, TWI –UK
- Alan Taylor, TWI-UK
- Amaya Arteche - INASMET-Spain
- Patricio Aguirre, INASMET-Spain
- Jose Barredas, INASMET-Spain
- Zsolt Illyefalvi, BME-Hungary
- Janos Pinkola, BME-Hungary
- Oliver Krammer, BME-Hungary
- Clara Santos, ISQ-Portugal
- Marco Estrela, ISQ-Portugal
- Eduardo Silva, ISQ-Portugal
- Rolim Carmo, ISQ-Portugal
- Marta Freitas – ISQ-Portugal
- João Luz Costa, ISQ-Portugal
- Márcio Silva, ISQ- Portugal
- Artur Denominato, ISQ-Portugal
- Bob Willis, SMART-UK
- Italo Fernandes, EWF—Portugal
- Marcus Kubanek, DVS-Germany
- Max Wach, JEMI-France

As well as to all the project partners involved in the project Research activities

Outline

- European Implementation of RoHS
- RoHS oriented SME European Research Projects
- LEADOUT Project – Overview & Final Results
- **Forthcoming related projects - ELECTROVALUE**

Forthcoming Projects

2009 - 2012

“Electric and Electronic Eco-Assembly Alternatives for the Valorisation of the End-of-Life Products in the Recycling Market”

- **Aims at the recovery and reuse of added value EE components less available in the market from e-waste through the development and implementation of a disassembly centre place at a recycling SME (Pilot company).**

Main Activities

- Life Cycle Analysis
- Waste management and EE components reuse assessment /Reliability issues
- Diassembly techniques, procedures & training
- Management tool
- Diassembly Pilot Centre
- Dissemination activities

A Quality and Technology Network

Thank you
Obrigada

Margarida Pinto
mmpinto@isq.pt

www.isq.pt

TEST STANDARDS

The main standards used for reliability testing and inspection are the following:

Visual inspection: IPC-A-610-D Class 3
Low temperature storage: EN-60068-2-48, EN-60068-2-1, Section 2. Test Ab.
High temperature storage: EN-60068-2-48, EN-60068-2-2, Section 2. Test Bb.
Thermal Cycling: IPC 9701 Cats 1,2&3 Test condition 1, NTC level E.
Mechanical shock-drop: EN-60068-2-32 Part 2.1 Test Ed: Free fall.
Thermal Shock by rapid change of temperature- air/air: EN-60068-2-14, Part 2. Test Na or Nb.
Component attachment strength: EN-60068-2-21 Test Ue3 Shear Test, Test Method 8.5.3.2